ELECTROLYTIC SURVEY OF LOOP DISTRICT IN CHICAGO AND ELECTROLYSIS OF WATER MAINS

BY

M. A. BUEHLER and J. H. JACOBSON

Armour Institute of Technology

1908

537.85
B 86

Illinois Institute
of Technology
UNIVERSITY LIBRARIES

AT 105
Buehler, M. A.
Electrolytic survey of loop
district in chicago and

For Use In Library Only

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

ELECTROLYTIC SURVEY OF LOOP DISTRICT IN CHICAGO

AND

ELECTROLYSIS OF WATER MAINS

A THESIS

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

PRESENTED BY

MARTIN A. BUEHLER JOSEPH H. JACOBSON

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

ELECTRICAL ENGINEERING

ILLINOIS INSTITUTE OF TECHNOLOGY
PAUL V GALVIN LIBRARY
35 WEST 33RD STREET
CHICAGO, IL 60616

JUNE, 1908

Approved
A. A. Noalke
Prof. of Elec Eng

F. M. Raymond
Dean of Eng. Dept.

F. C. Morrison
Dean of the Cultural Dept.

TABLE OF CONTENTS

1 - INTRODUCTION

2 - THEORY

Origin of Electrolysis.
Chemical Action.

3 - RETURN CURRENTS

Bonding.
Locality of corrosion.
Occurrances of Electrolysis.

4 - MEASUREMENTS

Voltage between rail & hydrant
Voltage between "L" structure & Hydrant.
Drop of potential in pipe.
Resistance in pipe.
Current in pipe.

5 - CONCLUSION

6 - DATA

20751

INTRODUCTION.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

ELECTROLYTIC SURVEY ON LOOP AND INVESTIGATION OF ELECTROLYSIS.

The subject of this thesis was to make a survey of the Chicago Loop District down town, including Wabash Avenue from Van Buren to Lake Street, Lake Street, from Wabash Avenue to Fifth Avenue, Fifth Avenue from Lake Street to Van Buren Street and Van Buren Street, from Fifth Avenue to Wabash Avenue.

We also investigated the same district for electrolysis of water pipes along same named streets. Curves of various types were plotted, showing relation of voltage, current, and different points along the route.

WABASH AV.

ANNEX
INSTITUTE OF [illegible]
LIBRARY.

THEORY.

It is a known fact that whenever a current passes from a water pipe, gas pipe, telephone cable, or most any metallic substance into the ground, corrosion takes place and a mere fraction of a volt may produce the corrosion.

It has been stated that anything under 1.5 volts can not produce any trouble, but this is not true. The statement is made that water will not dissociate below 1.5 volts. This is a mistake, however, because as current passes from iron to ground and then to iron, and produces corrosion, the counter, E. M. F. is only a small part of a volt.

In certain kinds of earth, current could leave a pipe with little or no effect, on account of the chemical action which neutralizes the corrosive effect.

It is not generally known that alternating current would effect water pipes or produce corrosion. This is true, however, as experiments have shown, but only in soil which is made up of a certain composition. Having this soil in a certain district, the effect is very small compared with that of dirrect current and only varies from a part of one per cent to two per cent of that which direct current would produce.

Most of the current which is found in water pipes comes from the electric surface or "L" road lines. The rails of these roads are not insulated from the ground, and hence, they will not carry the total current back to the Power House.

As all the current which leaves the rails, must return to the source of supply, some of this stray current takes t he water and gas pipes as a return conductor.

When salt is disolved in water, some of the molecules separate or dissociate into two parts, one part having a positive electrical charge, and the other a negative electrical charge, and these parts are called ions. The metal part, or the hydrogen, is the positive ion, and the acid part is the negative ion. An electrical current is transmitted through an electrolyte by the motion of these ions, and the rate at which the ions are liberated at the electrodes, is proportional to the current strength. With an oxidizing anode, the mass of anode corroded by one ampere in one second, is

equal to the electrochemical equivalent of the metal of the anode. This is .00029 gramme for iron. From this, mass of iron, corroded by one ampere in one year is .00029 X 60 X 60 X 24 X 365 grammes or . 00029 X 60 X 60 X 24 X 365 X .002 205 = 20 #.

If the electrolytic current were constant in a pipe and it would corrode the entire surface at the same time, it would be an easy matter to ascertain when the pipe would be destroyed, but this is not the manner in which electrolysis occurs. The current changes invariably, as shown by the curves. Some of this current may be corroding the iron and some may not. The water pipe acts as a conductor just the same as copper would. If a metalic connection were made from the track to the pipe at

some distance from the Power House, and a other connection made from the pipe to the rail at the Power House, the pipe would act as a mere shunt return and this current flowing would not be electrolytic. Of course, other currents enter and leave the pipe at different locations and it is these currents that leave the pipe which corrode the iron.

RETURN CURRENTS.

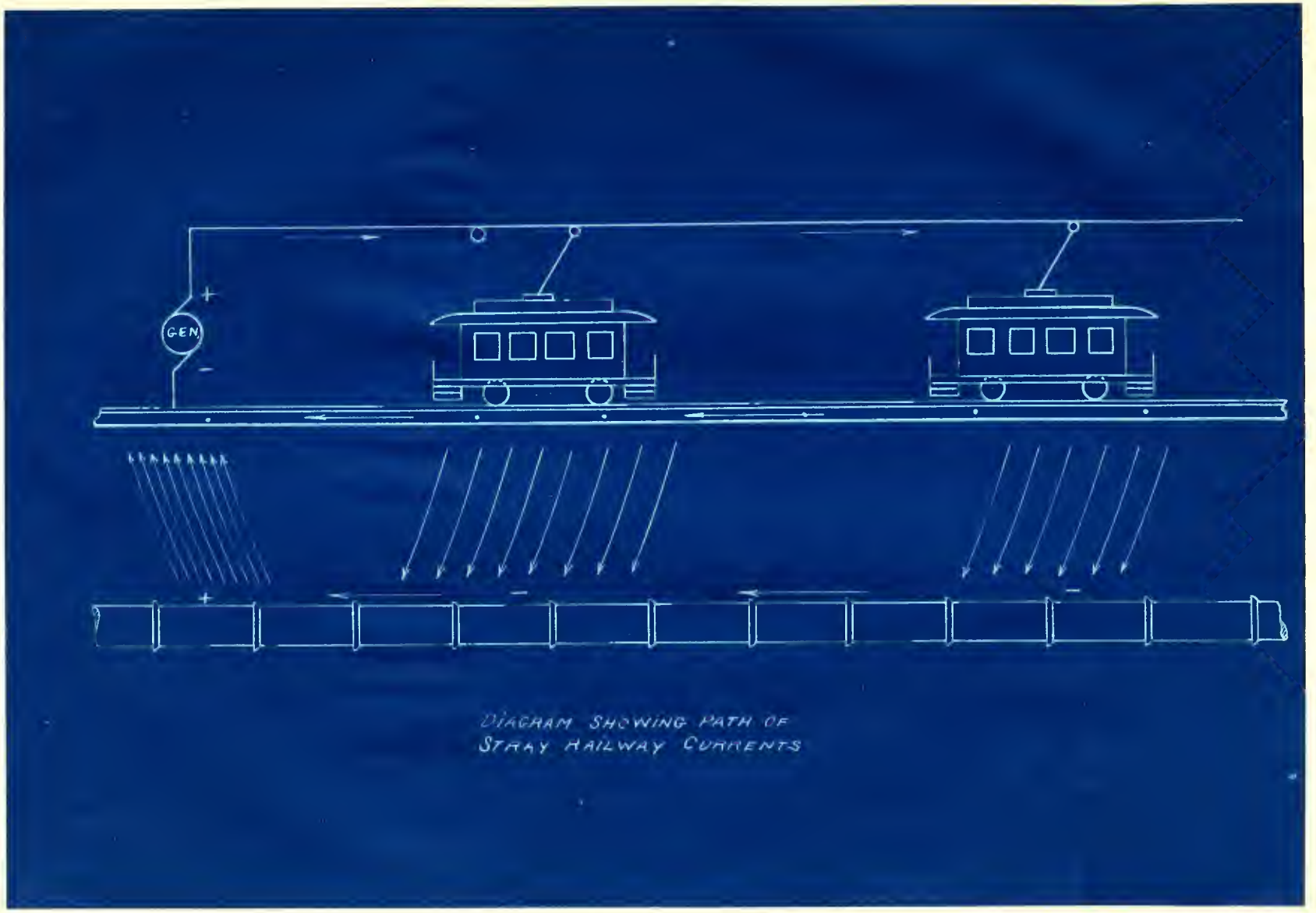


Diagram Showing Path of
Stray Railway Currents

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

It is now practically agreed that the reason for the extraordinary corrosion is to be found in the imperfect character of the return circuit of electric railways. When such railways were first constructed, the rails, in connection with the surrounding earth, were relied upon to carry all the current back to the generator. It was soon discovered, however, that the current would not confine itself to this path and that the resistance of the earth was far from being as low as was originally supposed. Bonding the rails, cross bonding supplementary wires and ground plates were than tried. The last was found to be of but little avail, while the copper bonds and supplementary wires were often themselves electrolyzed and bond wires had been frequently

far too small in cross section for the large current to be carried. There is little doubt that with a perfect return system, which is properly connected to systems of underground pipes, electrolytic disturbances will practically disappear in nearly all cities, although the corrosion action of the return currents has been so frequently noticed and commented upon, no one has really determined what actually occurs in the ground under the condition brought about by the operation of electric railway system. Two theories have been put forward relating to the corrosion. First, that it is simply due to chemical action, caused by ammonia, saltpeter and leakage from gas mains found in the earth. Second, that itis the result of electrolytic action. While simple chemical action undoubtedly has much to do with

shortening the life of pipes, it evidently can not produce effects of the magnitude of those noted above. The ordinary life of water and gas pipes, where chemical action alone is met, is said to be about twenty years, while the corrosive action, with which we are dealing, has destroyed new pipes in intervals of from a few weeks to a half dozen years. In every case of the corrosion to which we refer, an electric current has traveled along the pipe and corrosive action has taken place at the place where the current left the pipe. This is conclusive proof of electrolytic action. Secondary chemical reaction plays an important part in the final decomposition of the pipe and these are dependent upon the character of the salts in the soils, but the current is the starter. The electrolytic action of the current may occur in either one or two ways: First, by direct

electrolysis of iron and second by electrolysis of chemical compounds, which are held in the water of the soil, which results in secondary chemical reaction at the electrodes. All corroded iron pipes taken from the earth present practically the same appearance. They are generally pitted in several places, and although the pipe is covered with a layer of reddish oxide, the bulk of the corroded metal has generally been entirely carried away, presumably by a secondary chemical change.

There are many other endangered points which these simple tests will not reveal. Stray currents do not always take the paths from rail to pipe, along the pipe and back to rail or other return conductor, but frequently take round about paths passing from one piping system

to a second system, from this perhaps to a third system, or passing across pipes, shunting around high resistance points, producing electrolytic corrosion at every point of leaving the pipe for the ground.

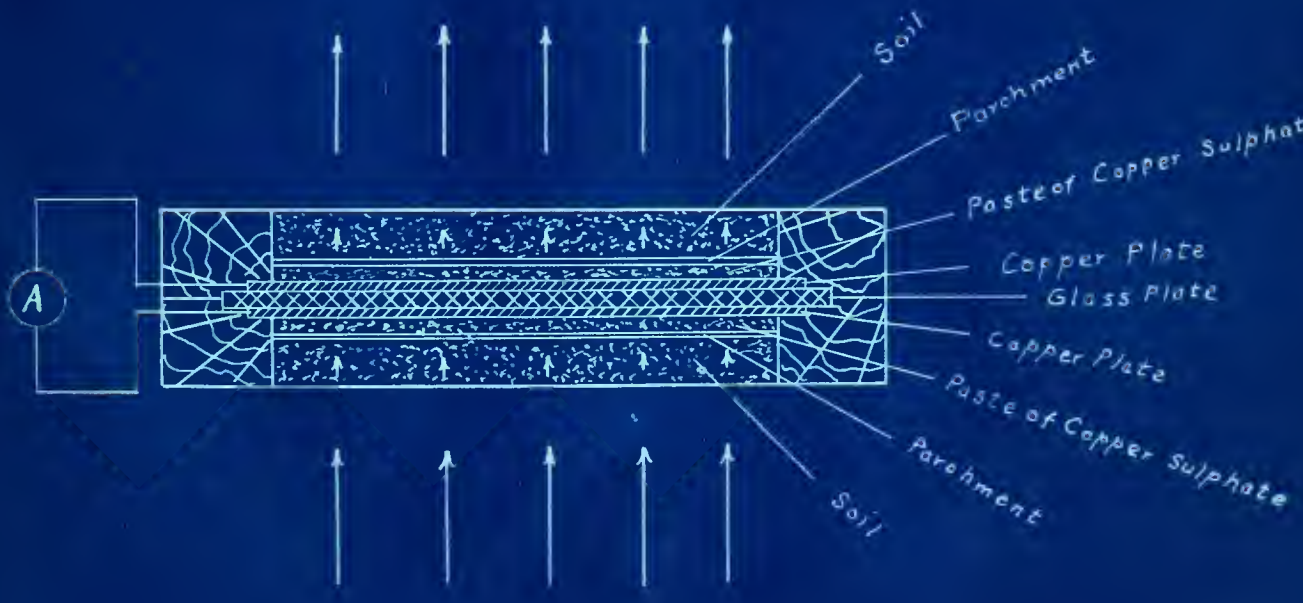
ARMOUR
INSTITUTE OF TECHNOLOGY

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

MEASUREMENTS.

It is possible to trace the path of current through the ground by measuring potential differences between different points in the ground. An iron rod driven into the ground is often used for making contact for such measurements. This, however, is not reliable, because the electromotive force of polarization of the iron in wet ground is dependent upon surface conditions of the iron and upon the ingredients of the ground. It is not constant and not necessarily the same for each of two rods in different parts of the earth. To over come this difficulty, the non-polarizable electrode is used, or to measure the current directly the earth ammeter derived by Professor Haber, as shown in figure, is used. This consists of a wooden frame, with two copper plates separated by mica

Earth Ampere meter



ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

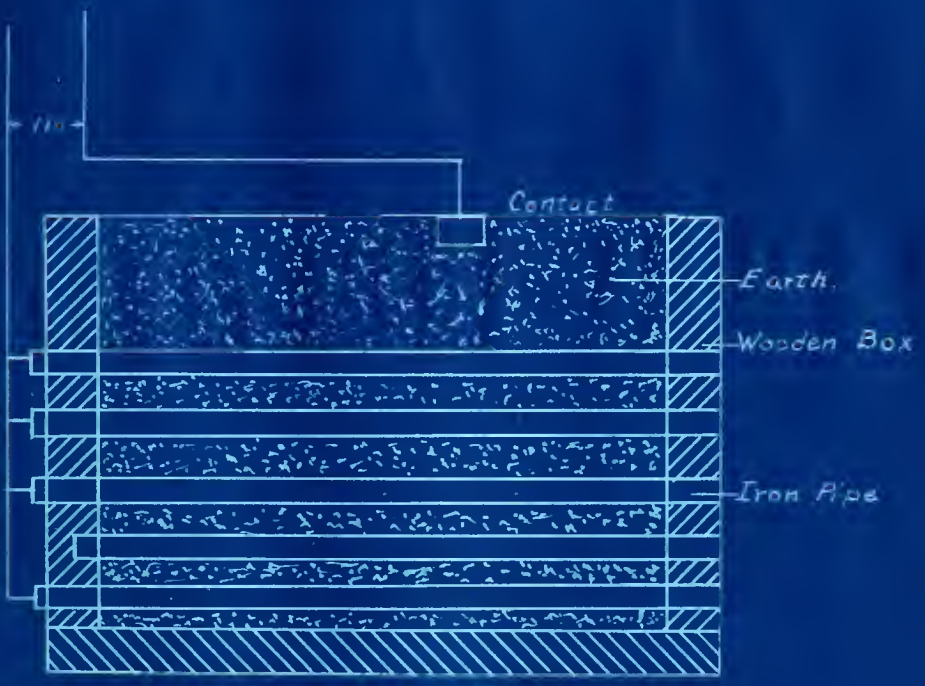
or glass. These copper plates are covered with a layer of paste made of copper sulphate and water with twenty per cent sulphuric acid, the thickness of paste being about 1/16 ". A wetted piece of parchment paper is laid over this part, and the remainder of the frame is filled with soil taken from the portion of ground where the current is to be measured. The frame is then placed in a suitable excavation in the ground where current is to be measured so that the current flow is as nearly as possible to the frame, and the latter is then completely covered up, the soil being tightly stamped in. Insulated copper wires are brought out from the plates and connected with a milli-amperemeter. This will indicate the current flowing through this section of the ground. The object of the copper

sulphate paste is to prevent polarization at the surface of the copper plates, which otherwise, would produce an electromotive force, opposing the flow of current through the meter. The meter is placed one to two inches from the pipe and parallel to it. This method is all very well and good, but to find the stray current in the Loop District of Chicago by this method, would cost thousands of dollars and, hence, make it beyond our reach or scope.

TESTS MADE BY
THE PEOPLES GAS LIGHT AND COKE COMPANY

Several tests have been conducted by the People's Gas Light and Coke Company on different insulating componds used for the protection of gas pipes. The gas pipes have been covered with a winding of cloth which was dipped in a fluid so as to protect it from electrolysis, but many complaints were sent in on account of not protecting it entirely, hence, this methcd will be discarded, especially as it is very expensive. Many samples of pipes were taken covered with a sort of paint and placed in a box, as shown by illustration. One box contained a clay soil, which was taken from a district in the city which gave trouble and the other

Method of Testing Pipe Insulation



ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

with a sandy earth. The current was allowed to flow from the top of the soil towards the pipe and it was found that after eight months, each pipe seemed to be pitted more or less. No substance has been found by the company as yet to prevent corrosion entirely. One pipe which was not electrically connected was placed between two other pipes which were connected electrically and it was found that this pipe was pitted, due to the current passing from the earth to the pipe and from the pipe, in order to reach the pipe below. The effect due to the sandy earth was not so great as that due to the clay earth.

VOLTAGE - SPACE CURVES.

These curves were obtained by taking the maximum drop of potential between the rail and fire plug or hydrant; also the elevated structure and hydrant. In this manner, we proceeded around the loop and then plotted the drops against space. It must be remembered that the points alone indicated on the curve sheet, represent the voltage and the space between the points do not necessarily represent anything. While these measurements were taken the voltmeter needle did not remain still for an instant, hence, to obtain a true curve, it would require a sensitive recording voltmeter, whose revolving dial has a fast and known speed. This, we were unable to obtain. One's first

impression would be that as the cars approached, the point where the voltmeter reading is being taken, the reading would increase to a maximum and decrease as the car faded out of sight. This impression is false, because there are too many stray currents entering the pipe from different sources. On Van Buren Street the voltmeter reads part of the time negative and part of the time positive. This, at least, means that there is electrolysis going on and is in an unstable condition. On Wabash Avenue, the highest possible voltage readings were obtained.

CORRODED PIPE ILLUSTRATION.

The lead pipe showing corrosion was obtained at 136 - 29th Street where the entire pipe was pitted from the front to the rear of the residence.

The Edison conduits run down the alley next to the house. An investigation showed that the wire was grounded and hence caused electrolytic corrosion. The Edison Company were obliged to tear up the alley and repair the defect.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

CURRENT TIME CURVES

These curves were obtained by taking the drop across a known length of pipe. The reading was taken every minute for a half hour. The resistance of the pipe was measured as was indicated in the foregoing. The current may be obtained by ohms l aw I = E/R.

These currents are, of course, only approximately correct, because it is impossible to know the true resistance of the pipe without opening the main and inserting an ammeter. This is an impossibility.

Van Buren Street showed an unstable condition in this test. An investigation of the car tracks on Van Buren Street shows that they are in poor condition and should be renewed. At

the present time, Wabash Avenue
is receiving new tracks and,
hence, the electrolytic conditon
is again changed.

APPARATUS USED IN OBTAINING DATA.

400 ft. # 14 copper wire

1 (0-100) M voltmeter

1 (0-10) voltmeter

2 knife contacts

1 (0-250) ammeter

1 water rheostat

1 file

1 ground rod

METHODS OF TAKING MEASUREMENTS ON LOOP

A survey was just made by taking the drops of potential from water pipe fire plug to rail and also from plug to "L" structure. The quantity and polarity were observed and recorded in a note book. This was done for the entire loop and these curves were potted with distance on the "X" axis and voltage on the "Y". These results are, of course, qualitative as the resistance of the soil varies at different points. At Van Buren & Clark streets, the reading was negative, which indicated the current was passing from the pipe to the rail and this is what causes corrosion or pitting of the pipe and hence gives rise to disastrous results. Measurements were taken

with the milli-voltmeter between two fire plugs on the same side of the street. To apply Ohm's law, it is necessary to know the resistance of the pipe. The resistance of the joint is many times the resistance of the pipe itself.

By the kindness of Mr. Baker, who is an Engineer for the City of Chicago Water Pipe Extention Department, we were able to receive a joint and pipe which we found the resistance of by the fall of potential method. The pipe was taken from the ground in the loop district after being in service for three years. Knowing the resistance of the joint and 12 ft. of pip e, we found the resistance per joint foot. Now, we were able to find the current flowing in the pipe by the equation I = E/R. Readings were taken at one minute intervals

from fifteen to thirty minute runs at the same plugs. In this way, we proceeded around the loop again. Because a certain amount of current flows in a pipe at a definite point, does not necessarily mean that electrolysis is going on at that point, but there is some point where it is in action.

To see whether or not the current flowing in a main varied with the railway load, we took several readings after midnight on May 28th. We found a great difference in the voltage drop in the main and also a decided difference in drops from hydrant to rail and "L" post. When we tested this same place in the day time, we got both readings positive and at night the drop to the rail was -1.0 volt, while the other was -.6 volts. Of course, these are maximum volts, but at any rate, show what a decided difference there is. The drop in a length of pipe was a maximum while an "L" train was passing, but in between hovered around zero. On the following page is a tabulated table showing our night readings.

Van Buren Street, Between State
and Wabash Avenue, May 28th, 1908.

Length 149.5 ft.
Diam 8 inches

TIME	E Volts.
12;09	.045
12;10	.070
12:11	.20
12:12	.030
12:13	.0.0
12:14	.045
12:15	.050
12:16	.030
12:17	.030
12:18	.040
12:19	.0
12;20	.0

NIGHT READINGS.

Drop from hydrant to rail -1.0 volts

Drop from hydrant to "L" post -. 60 volts

DAY READINGS.

Drop in main was 1.2 volts

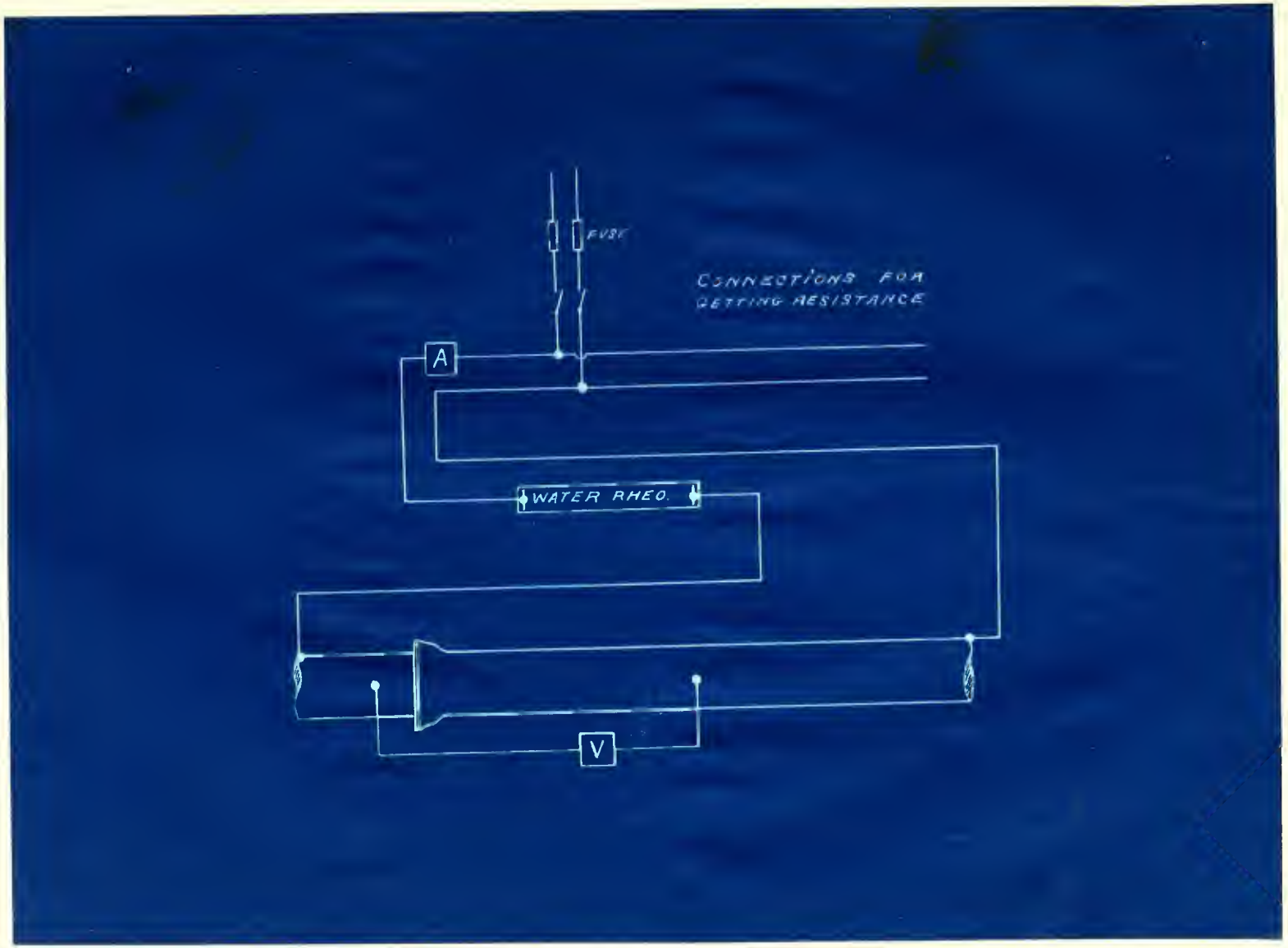
Drop from hydrant to rail 3.1 volts

Drop from hydrant to "L" post about zero.

CONCLUSION.

MEASUREMENTS OF RESISTANCE OF PIPE JOINT OF 6 " PIPE 12 '

This pipe was measured at 22nd Street and Ashland Avenue at the City Water Pipe Supply Department. A water rheostat was used tc reduce the current. The pipe named was in service for three years and it was evident that the joint resistance increases with the time it is in the earth. It was necessary to use a (0 - 10) voltmeter for the resistance of the pipe joint, while for the pipe, without the joint, a milli-voltmeter was used.



MASSACHUSETTS
INSTITUTE OF TECHNOLOGY
LIBRARY

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

METHODS OF PREVENTING ELECTROLYSIS.

Using alternating current nearly eliminates it. If direct current must be used, have no ground returns for the trolly current, but have a double trolly so as to return the current to the Power House in that manner. If ground returns must be used, all bonding of rails should be welded because the joints are the places where the stray current leaves the rails.

Methods have been proposed for insulating the pipe by means of a preparation, but this is not the best method, because if a certain portion of the pipe should be disposed by some carelessness or wear, the stray current would pit this

spot and hence destroy the main. A cheap method may be used by connecting the rail to the pipe at short intervals, and hence allow the pipe to act as a shunt for the current. Since current always passes through the path of the least resistance, the current would go through the wire to the pipe, instead of through the ground to the pipe. Of course, this method is not entirely satisfactory, but it is better than no protection.

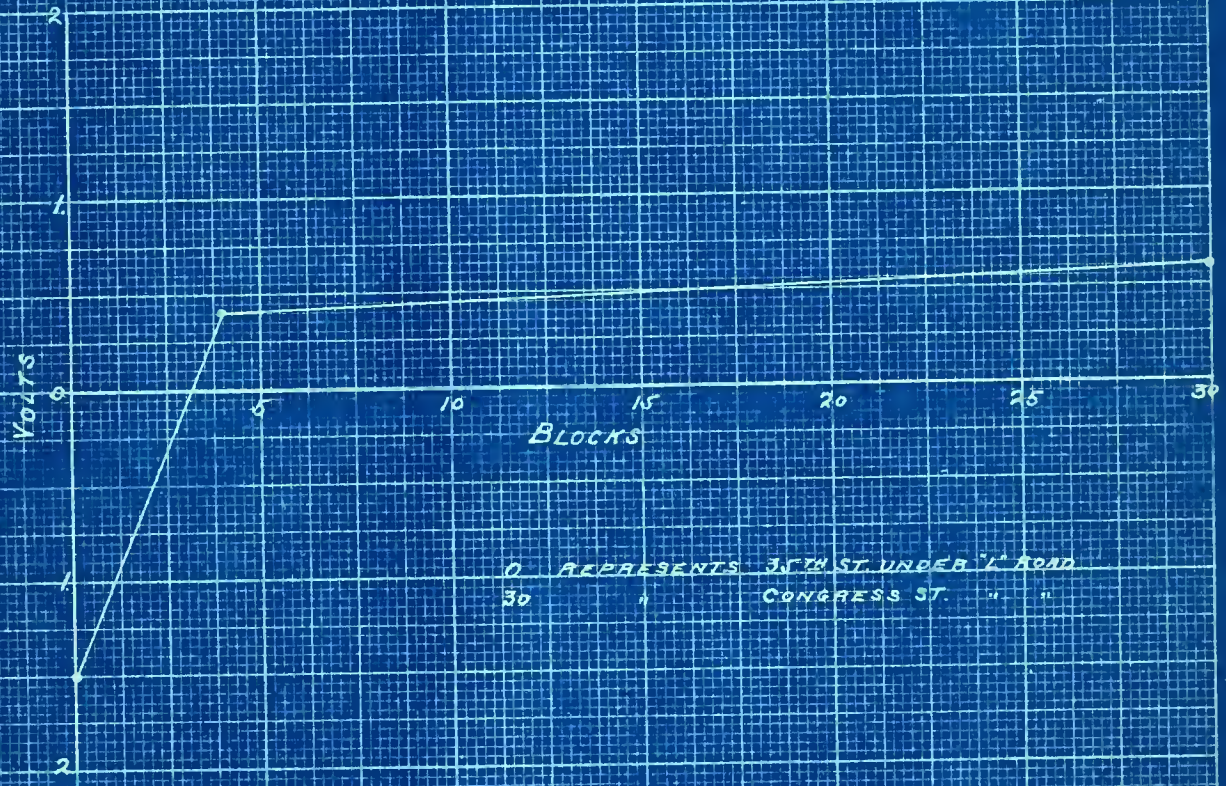
DATA.

DATA SHOWING HOW VOLTAGE DECREASES AND TENDS TO BECOME NEGATIVE AS PIPING NEARS THE POWER HOUSE

Starting at 33rd and State Streets and going to the Power House at 39th and State Streets, we gathered the following data. This Power House does not belong to the City Railway, but to the Elevated Road.

The result, however, shows that the first statement made is true, since the City Railway's plant is just a little South of 39th Street.

Curve Showing How Voltage Declines as You Near Power House



0 Represents 35th St. under "L" Road

30 " Congress St. " "

M.A.B.
J.H.J.

No. 346

Eugene Etzgen Co. Chicago-New York

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

STATE STREET.

CROSS STREET	Average voltage between hydrant & Rail (positive)
33rd - 34th West Side	5.5
34th	5.25
34 - 35th	5.2
35th	5.4
35th - 36th	4.5
36th	5.0
38th	3.5
38th - 39th	2.5
39th	1.75

On 39th Street under the elevated road, the voltage between structure and hydrant was 1.5 negative, while voltage between rail and hydrant was 3.2 positive.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

WABASH AVENUE.

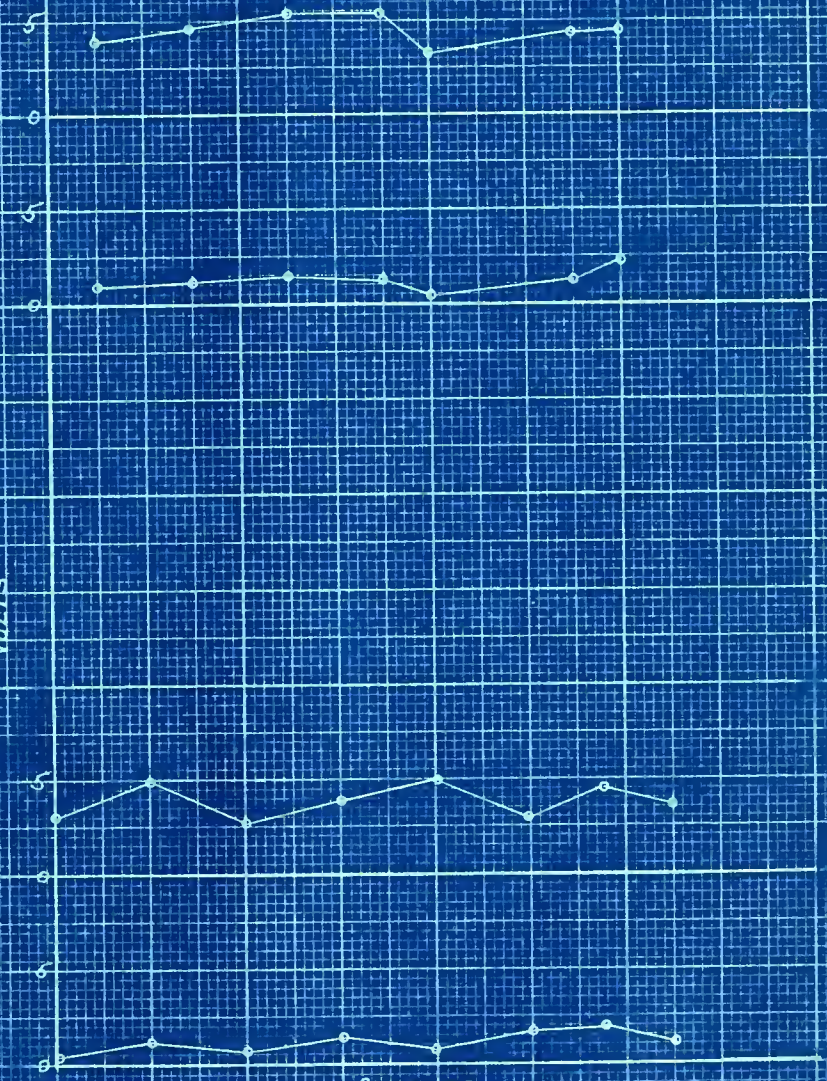
Feb.7th,1908 -1- 3:30 P.M.

CROSS STREET	VOLTAGE Hyd & rail	VOLTAGE Hyd & "L" Structure
Randolph-Lake-East Side	3.6	1.2
Randolph-West Side	4.5	2.3
Randolph-Wash-East Side	4.5	2.0
Randolph-Wash-West Side	4.5	1.2
Washington-East Side	3.0	2.0
Madison-East Side	5.0	7.5
Madison-West Side	3.5	.5
Madison-Monroe-West	5.5	1.25
Monroe-East Side	4.0	1.5
Monroe-Adams-West Side	5.5	1.5
Adams-East Side	2.75	.7
Adams-Jackson-West Side	4.75	1.25
Jackson-East Side	5.00	1.2
Jackson-Van Buren-West	4.00	1.0
Van Buren-East Side	5.00	.5

WABASH AV.

CURVES SHOWING VOLTAGE DROP FROM HYDRANT TO RAIL AND FROM HYDRANT TO "L" POST

1. WEST SIDE ST. RAIL
2. " " " "L" POST
3. EAST " " RAIL
4. " " " "L" POST



M.A.B.
J.H.J.

NO 345

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

LAKE STREET.

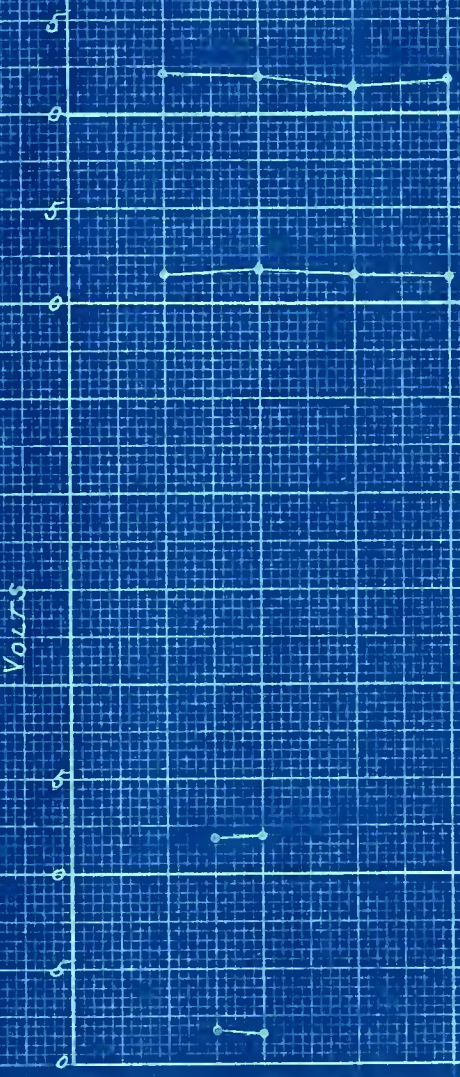
Mar. 7th,1908 2-4 P.M.

CROSS STREET.	VOLTAGE Hyd & rail	VOLTAGE Hyd & "L" Structure
State-N. E.Corner	1.8	.9
State-N. W. Corner	2.2	1.5
State-Dearborn-South	1.95	1.8
Dearborn-S.E.Corner	2.0	1.5
Dearborn-N.W.Corner	2.1	1.8
Clark-N.W.Corner	1.5	1.5
La Salle-N.W.Corner	1.8	1.4

LAKE ST.

CURVES SHOWING VOLTAGE DROP FROM HYDRANT TO RAIL AND FROM HYDRANT TO "L" POST.

1. NORTH SIDE ST. RAIL
2. " " "L" POST
3. SOUTH " " RAIL
4. " " "L" POST



STREETS

WABASH
STATE
DEARBORN
CLARK
LA SALLE
FIFTH

M.A.B.
J.H.J.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

VAN BUREN STREET.

Mar.13th,'08 1.55-340

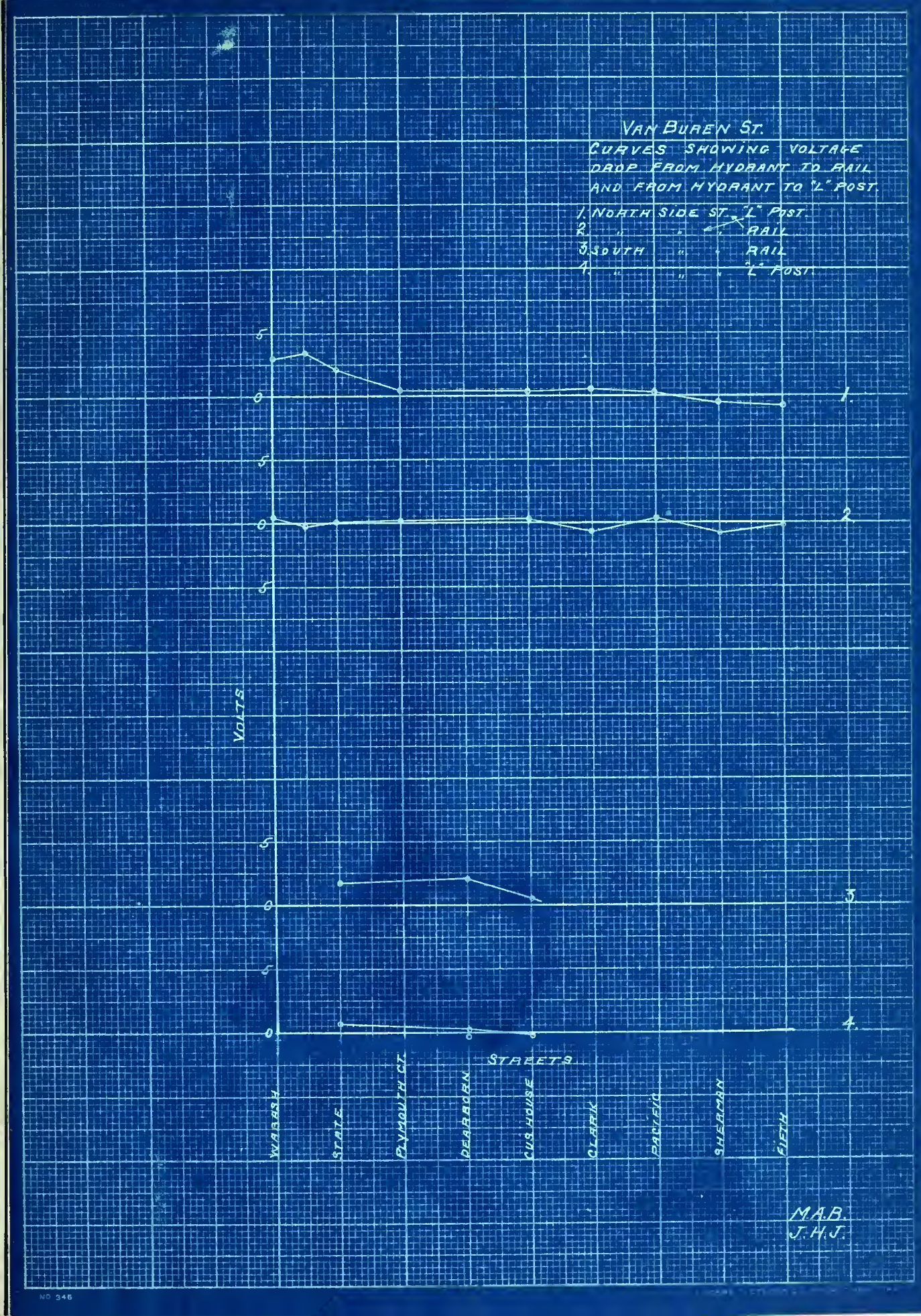
CROSS STREET

	VOLTAGE Hyd & rail	VOLTAGE Hyd & "L" Structure
State-S.E.Corner	1.75	.4
Dearborn-S.W.Corner	.2	-.01
CustomHouse Pl-S.W.	. 5	-.0075
Fifth Ave-N.E.Corner	-.75	-.1
Sherman-N.E.Corner	-.3	-.8
La Salle-N.E.Corner	-.25	-.25
Clark-N.W.Corner	.5	-.6
Custom-N.W.Corner	.4	-.25
Plym.Ct.-N.W.Corner	.25	-.1
State-N.W.Corner	2.1	0
State & Wabash-N.	3.1	-.1

VAN BUREN ST.

CURVES SHOWING VOLTAGE DROP FROM HYDRANT TO RAIL AND FROM HYDRANT TO "L" POST.

1. NORTH SIDE ST. "L" POST.
2. " " " RAIL
3. SOUTH " " RAIL
4. " " " "L" POST.



M.A.B.
J.H.J.

NO 345

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

FIFTH AVENUE.

Mar.13,'08.

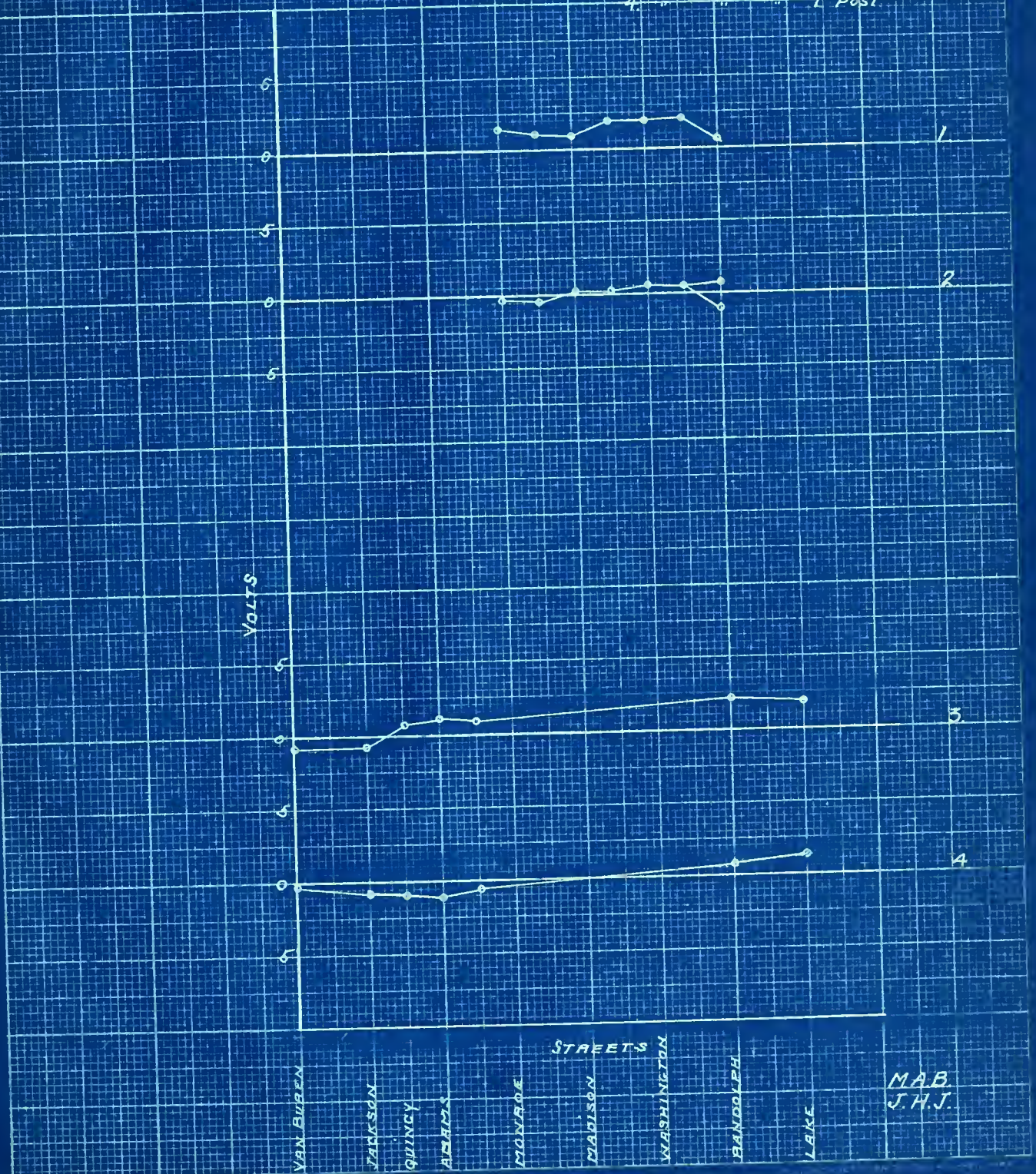
CROSS STREET.

	VOLTAGE Hyd & rail	VOLTAGE Hyd & "L" Structure
Randolph-N.E.Corner	2.1	.75
Randolph S.W.Corner	.8	1.1
Randolph-Washington-S.W.	2.2	.5
Washington-N.W.Corner	1.9	.5
Washington-Madison-N.	2	.2
Madison-S.W.Corner	1	.1
Madison-Monroe-S.W.Cor	1.2	-.2
Monroe-N.W.Corner	1.5	-.1
Monroe-Adams-S.E.Corner	1.	-.3
Adams-S.E. Corner	1.1	-1
Quincy-N.E.Corner	.25	-.4
Jackson-N.E.Corner	-.4	-.65

FIFTH AV.

CURVES SHOWING VOLTAGE DROP FROM HYDRANT TO RAIL AND FROM HYDRANT TO "L" POST

1. WEST SIDE ST. RAIL
2. " " " "L" POST
3. EAST " " RAIL
4. " " " "L" POST



M.A.B.
J.H.J.

NO. 345

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

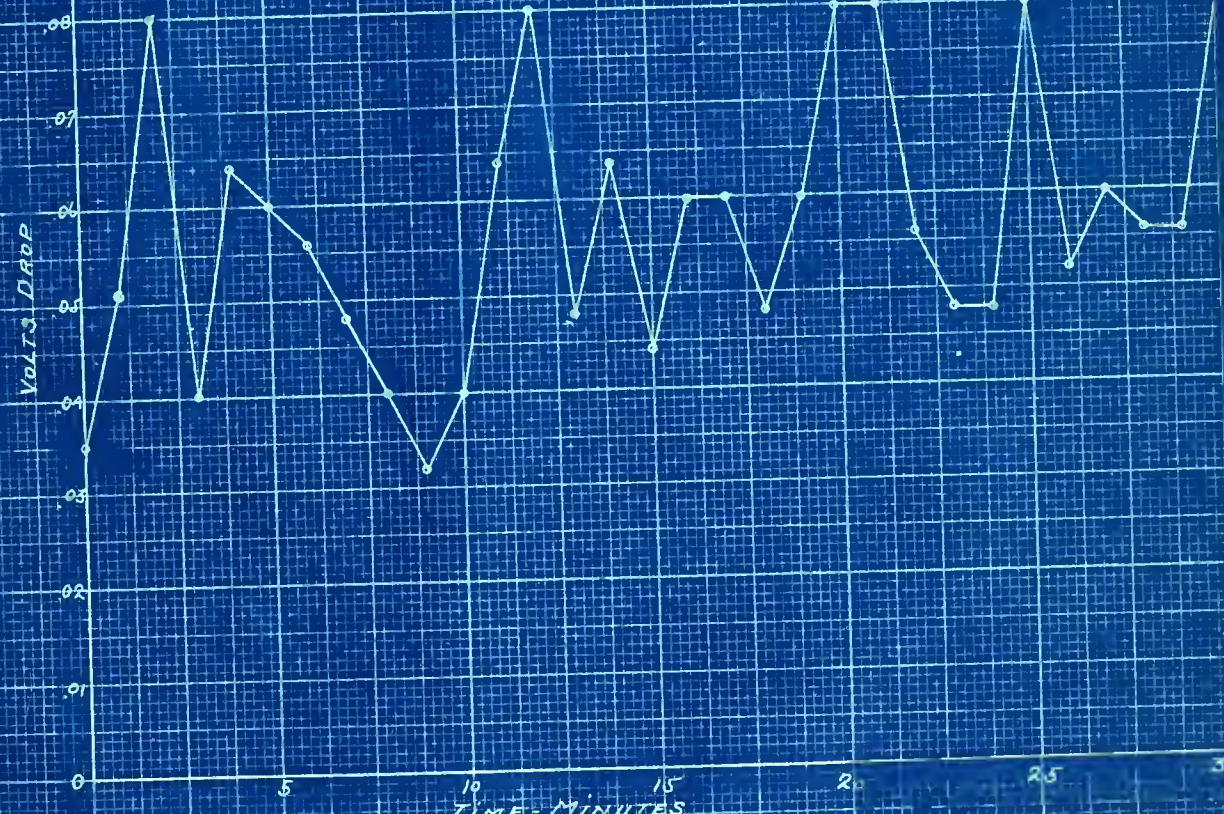
LAKE STREET, LA SALLE & FIFTH AVENUE.

TIME	E	I
11:12	.045	.035
11:13	.065	.051
11:1 4	.1	.08
11:15	.05	.04
11:16	. 080	.064
11:17	.075	.06
11:18	.070	.056
11:19	.060	.048
11:20	.050	.04
11:21	.040	.032
11:22	.050	.04
11:23	. 080	.064
11:24	0.100	.08
11:25	.060	.048
11:26	.080	.064
11:27	.055	.044
11:28	.076	.06
11:29	.076	.06
11:30	.060	.048
11:31	.075	.06
11:32	0.100	.08
11:33	0.100	.08
11:34	.070	.056
11:35	.060	.048
11:36	.060	.048
11:37	0.100	.08
11:38	.065	.052
11:39	.075	. 06
11:40	.070	.056
11:41	.070	.056
11:42	.100	.08

Length of pipe = 328 ft.
Diam. of pipe 12 inches.
Joint ft. resistance of 12" pipe .00383 ohms
Total resistance = 1.25 ohms.
Current toward the East.

VOLTAGE DROP IN PIPE.

LAKE ST. BET. 5TH AV. + LASALLE ST.
NORTH SIDE OF STREET.
TIME: 11:15 A.M. APRIL 21, 1906.
L = 328 FT. D = 12 INS.



M. A. B.
J. H. J.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

FIFTH AVENUE.

April21st, '08

RANDOLPH & WABASH, SOUTHWEST.

TIME	E	I
12:10	.008	.0058
12:11	.009	.00655
12:1 2	.007	.00507
12:13	.008	.0058
12:14	.0095	.0069
12:15	. 01	.00728
12:16	.011	.008
12:17	.011	.008
12:18	.009	.00655
12:19	.011	.008
12:20	.010	.00728
12:21	.010	.00728
12:22	.009	.00655
12:23	.008	.0058
12:24	.0095	.0069
12:25	.009	.00655

Length of pipe = 179 ft.

Diam. of pipe 6 inches.

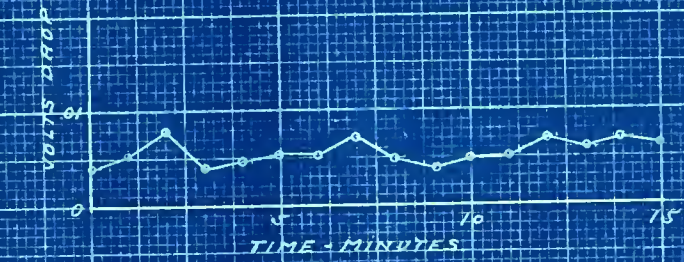
Joint ft. resistance of 6 inch pipe .00767

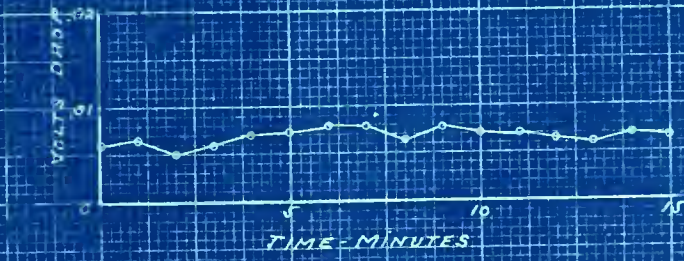
Total resistance = 1.37 ohms.

Current going North.

VOLTAGE DROP IN PIPE

1. FIFTH AV. BETWEEN RAND. & WASH. STS. WEST SIDE OF STREET. L=179FT. D=6 INS. TIME=12.10 P.M. APRIL, 21, 1908.
2. FIFTH AV. BETWEEN MAD. & MON. STS. WEST SIDE OF STREET. L=208FT. D=8 INS. TIME=1.30 P.M. APRIL, 21, 1908.





M.A.B.
J.H.J.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

VAN BUREN STREET, April 22nd, 1908.

CUSTOM HOUSE PLACE AND DEARBORN

SOUTH SIDE ST.

TIME	E	I
3:06	.3	.038
3:07	.36	.0417
3:08	.3	.038
3:09	-.25	-.0298
3: 10	.25	.0298
3:11	-.1	-.0119
3:12	.35	.0417
3:13	.05	.0059
3:14	.15	.0059
3:15	.1	.0119
3:16	.3	.038
3;17	.15	.0178
3:18	.05	.0059
3:19	-.1	-.0119
3:20	.1	.0119

Length of pipe = 140 ft.

Diam. of pipe = 8 inches.

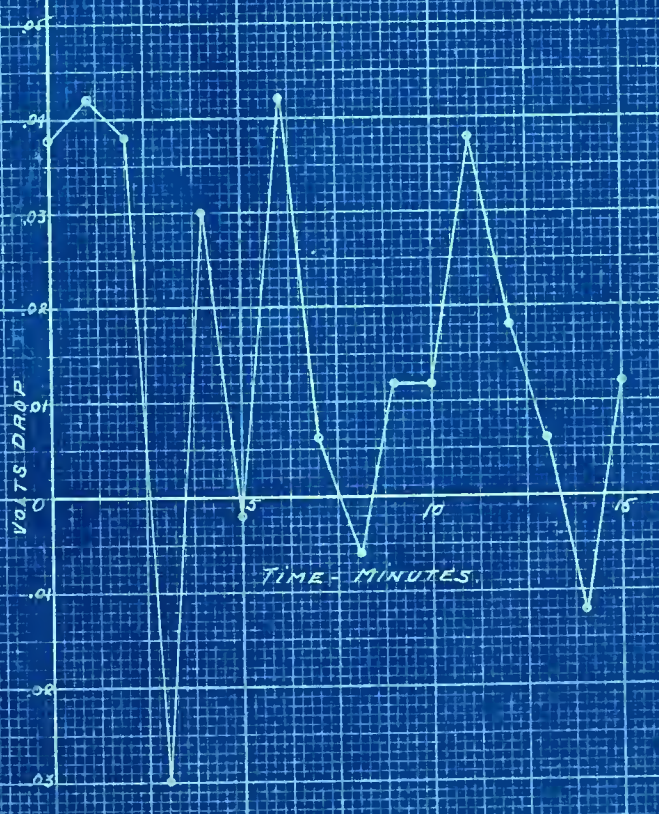
Joint ft. resistance of 8 inch pipe = .006 ohms.

Total resistance = 84 ohms

Current flowing Eastward.

VOLTAGE DROP IN PIPE

VAN BUREN ST. BET. DEAR. ST. & CUSTOM HS. PL.
SOUTH SIDE OF STREET.
TIME - 3.00 P.M. APRIL 22, 1908.
LENGTH - 1,140 FT. D = 8 INS.



MAB
J.H.J.

NO 346

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

WABASH AVENUE APRIL 22nd, 1908

TIME	E	I
3:31	.3	.147
3:32	.45	.22
3:33	.4	.196
3:34	.35	.172
3:35	.35	.172
3:36	.25	.123
3:37	.40	.196
3:38	.35	.172
3:39	.4	.196
3:40	.35	.172
3:41	.25	.123
3:42	.4	.196
3:43	.5	.245
3:44	.45	.22
3:45	.25	.123
3:46	.3	.147
3:47	.35	.172
3:48	.4	.196
3:49	.3	.147
3:50	.3	.147
3:51	.4	.196
3:52	.35	.172
3:53	.5	.245
3:54	.45	.22
3:55	.48	.22
3:56	.35	.172
3:57	.4	.196
3:58	.5	.245
3:59	.35	.172
4:00	.4	.196
4:01	.4	.196

Length of pipe = 241 ft.

Diam of pipe = 8 in.

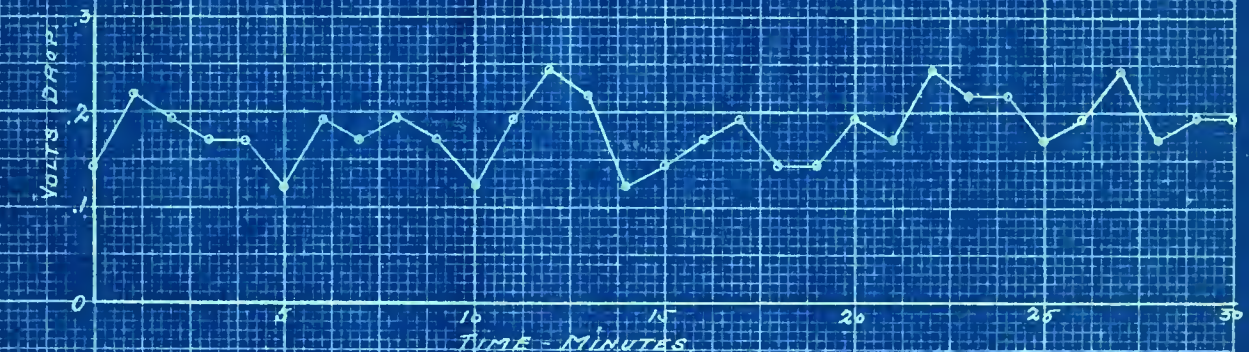
Joint ft. resistance of 8 in. pipe = .006

Total resistance = 2.046

Current flowing North.

Voltage Drop in Pipe

Wabash Av. Bet. Rand & Wash. Sts.
East Side of Street.
Time - 5:30 P.M. April 22, 1908.
L - 291 Ft. D - 8 Ins.



M.A.B.
J.H.J.

KEUFFEL & ESSER CO. CHICAGO-NEW YORK

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

VAN BUREN STREET, WABASH & STATE.

TIME	E	I
2: 35	.6	.675
2:36	.9	1.01
2:37	.5	.562
2:38	.3	.337
2:39	.5	.562
2:40	.55	.618
2:41	.25	.281
2:42	. 6	.675
2:43	.4	.45
2:44	.3	.337
2:45	.4	.45
2:46	.5	.562
2:47	.25	.281
2:48	.5	.562
2:49	.5	.562
2:50	.4	.45
2:51	.55	.618
2:52	.30	.337
2:53	.4	.45
2:54	.7	.787
2:55	.6	.675
2:56	.3	.45
2:57	.45	.506
2:58	.5	.562
2:59	.5	.562
2:60	.35	.393
3:01	.75	.506
3:02	.35	.393

Length of pipe = 149.5 ft.

Diam. of pipe = 8 inches.

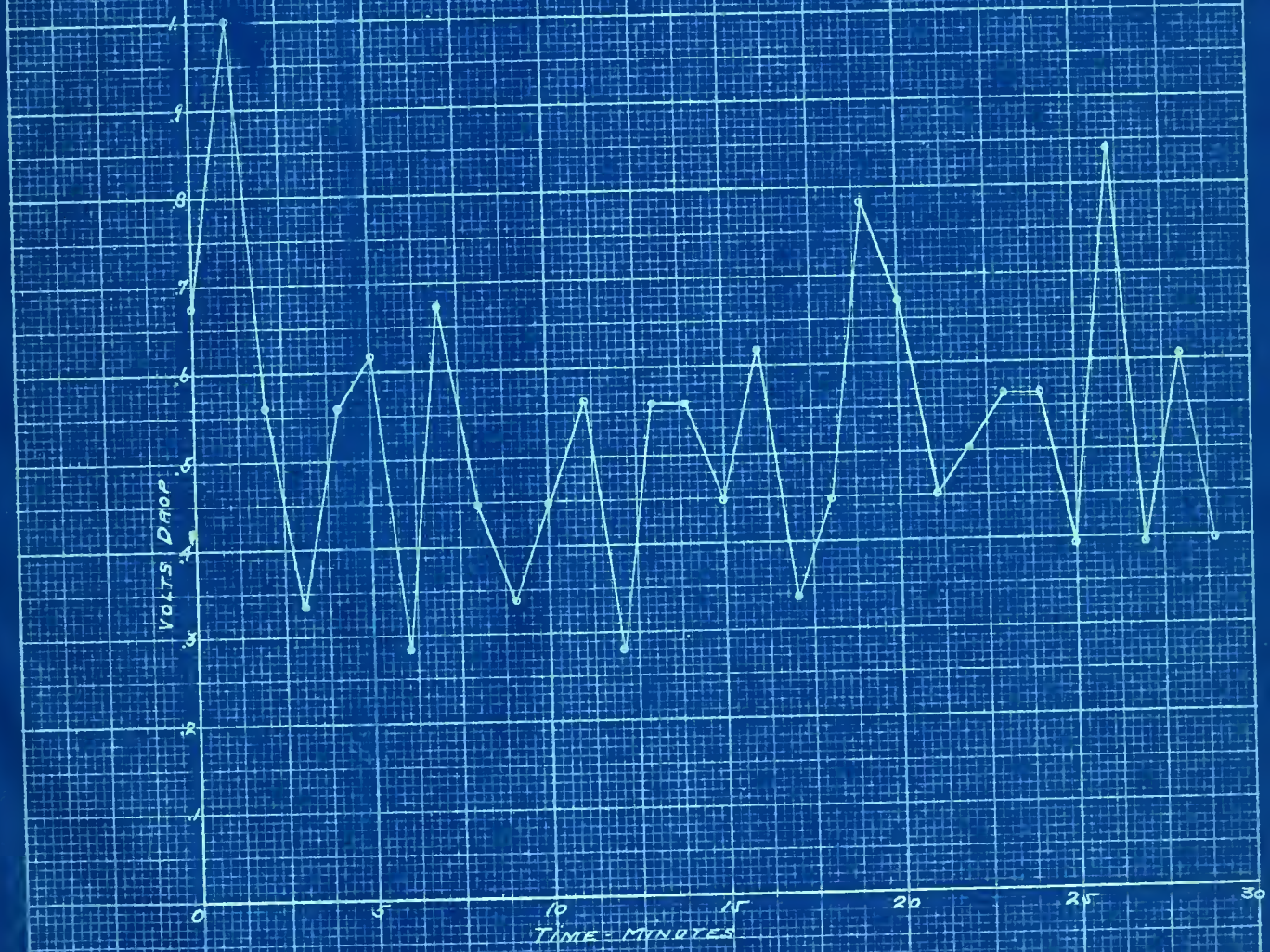
Joint ft. resistance of 8 inch pipe .006 ohms.

Total resistance = .897 ohms

Current flowing Eastward.

Voltage Drop in Pipe

Van Buren St. Between State St. & Wabash Ave.
North Side of Street.
Time - 2.35 A.M. April 22, 1902.
Length - 149.6 Ft. 8 In. Main



M. A. B.
J. H. J.

EUGENE DIETZGEN CO. GM CASE-NEW YORK

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

FIFTH AVENUE, MADISON & MONROE.

APRIL 22nd, 1908

TIME	VOLTAGE	I
1:19	.005	.004
1:20	.0065	.0052
1:21	.01	.008
1:22	.005	.004
1:23	.006	.0048
1:24	.007	.0056
1:25	.0065	.0052
1:26	.009	.0072
1:27	.006	.0048
1:28	.005	.004
1:29	.006	.0048
1:30	.0065	.0052
1:31	.009	.0072
1:32	.0075	.006
1:33	.0095	.0076
1:34	.008	.0064

Length of pipe = 208 ft.

Diam. of pipe = 8 inches.

Joint ft. resistance of 8 inch pipe = .006 ohms.

Total resistance = 1.248 ohms

Current flowing Northward.

ELECTRICAL RESISTANCE PIPE 12 FT. LONG INCLUDING

Joint diam. = 6 inches

R=E/I= 1.05/106=	.099	ohms	resis	per	foot	.008 25
	.062	"	"	"	"	.00516
	.0903	"	"	"	"	.00762
					3(	.2303
						.00767
7 ' 8 " length	.0855	"	"	"	"	.00711
4 ' 6 " length	.0241	"	"	"	"	.00202
2 ' 4 " length	.089	"	"	"	"	.00382

WITHOUT JOINT

4 ' 1 " length	.000395	"	"	"	"	.0000975
7 ' 3 " length	.000567	"	"	"	"	.0000753
9 ' 5 " length	.000617	"	"	"	"	.0000655
					3 (	.0002383
						.0000794

AVERAGE JOINT FOOT RESIS .00767 ohms.

REFERENCES.

ENGINEERING INDEX UNDER STRAY CURRENTS.

STRAY CURRENTS FROM ELECTRIC RAILWAY - MICHALKE

AMERICAN GAS LIGHT ASSOCIATION.

REPORT OF COMMITTEE ON ELECTROLYSIS
BY PROFESSOR GANS

ELECTROLYSIS - FOUNTAINE AND BERLEY

WESTERN ELECTRICIAN.

AUGUST 31st,1895

537.85
B 36
Armour Institute of Technology Library
CHICAGO, ILL.
DEMCO-MADISON-WIS